A STUDY OF DARK, HARD KERNEL AND PROTEIN CONTENT OF HARD RED SPRING WHEAT[1]

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INTRODUCTION

Market grades for hard-wheat types have usually provided a classification on the basis of dark or hard-kernel content. For a number of years before the present Federal grades were promulgated the dark, hard-kernel content was used as a basis for grading spring wheat. The present Federal grades provide for three subclasses of hard red spring wheat, as follows: (1) Dark northern spring, containing 75 per cent or more of dark, hard, and vitreous kernels; (2) northern spring, containing less than 75 per cent and more than 25 per cent of dark, hard, and vitreous kernels; and (3) red spring, containing not more than 25 per cent of dark, hard, and vitreous kernels. Hard spring, containing 85 per cent or more of dark, hard, and vitreous kernels, is a premium grade under the subclass dark northern spring.

The present Federal grades provide similar subclasses for hard red winter and durum wheats. The use of the dark or hard-kernel content as a basis for grading has been confined to "hard" wheat types, which will generally average higher in protein or gluten content than other types, and which will also show greater variation in physical characteristics and composition according to season and location. Dark or hard-kernel content is used as a basis for grading hard wheats on the assumption that the percentage of dark, hard, vitreous kernels is an indication of the protein content of the wheat.

It is generally conceded that dark, hard, vitreous kernels contain more protein than light-colored, starchy kernels from the same lot of wheat. Snyder[2] found that "when the two types of seed, light and dark, were selected from the same lot of wheat, the darker seeds in all samples analyzed were found to be richer in protein." Snyder also found that light seeds and dark seeds from different sources contained different amounts of protein.

Roberts[3] attempted to correlate crushing strength of hard winter wheat with protein content, but found no significant correlation. The results of his work indicate that crushing or breaking strength is probably of less importance as indicating protein content than the color of the kernel.

Mangels and Sanderson[4] found a positive correlation between protein content and dark, hard kernels for the crops of 1922, 1923,

[1] Received for publication Aug. 19, 1926; issued February, 1927. Contribution from the department of Milling; published with the permission of the director of experiment station.

[2] SNYDER, H. WHEAT AND FLOUR INVESTIGATIONS. Minn. Agr. Expt. Sta. Bul. 85: 179–224, illus. 1904.

[3] ROBERTS, H. F. RELATION OF HARDNESS AND OTHER FACTORS TO PROTEIN CONTENT OF WHEAT. Jour. Agr. Research 21: 507–522, illus. 1921.

[4] MANGELS, C. E., and SANDERSON, T. THE CORRELATION OF THE PROTEIN CONTENT OF HARD RED SPRING WHEAT WITH PHYSICAL CHARACTERISTICS AND BAKING QUALITY. Cereal Chem. 2: 107–112. 1925.

and 1924, but the coefficient of correlation showed considerable seasonal variation.

Under the Federal system of grading hard red spring and hard red winter wheat, the term "dark, hard, and vitreous" kernels is used, but in actual practice wheats are divided into subclasses on the basis of color only. Kernels which are dark in color, however, are usually hard and vitreous, and at present no convenient or practical method of measuring "hardness" or "vitreousness" is available.

The North Dakota Experiment Station has collected data on dark kernels and protein content for four crop years, and now has information on more than 1,000 samples from the crops of 1922 to 1925, inclusive. Because of the importance of the relationship between dark kernels and protein content it was deemed advisable to make a careful study of these data.

CORRELATION BETWEEN PROTEIN CONTENT AND PERCENTAGE OF DARK KERNELS IN HARD RED SPRING WHEAT

The results of correlation studies made on the North Dakota crops of 1922 to 1924 have already been published.[4] Table 1 brings together the results of correlation studies for the four crop years 1922 to 1925, inclusive.

TABLE 1.—*Correlation between protein content and dark-kernel content of hard red spring wheat from North Dakota crops, 1922–1925*

Year	Number of samples	Mean protein content	Mean dark-kernel content	Coefficient of correlation	Probable error
		Per cent	*Per cent*		
1922	90	12.12	83	0.660	±0.041
1923	199	13.35	73	.067	±.047
1924	316	11.35	79	.453	±.030
1925	436	12.31	90	.299	±.043

The coefficients of correlation for the four crop years show a wide range in magnitude. In the 1922 crop there is a marked correlation between dark kernels and protein content, and in the 1924 crop there is a significant correlation, but in the 1925 crop the correlation is less than 0.3, and in 1923 there is practically no correlation. The 1923 crop also shows the highest mean protein content and the lowest mean dark kernel content, but this apparent discrepancy is due to the fact that many of the samples from the 1923 crop were weather damaged. These weather-damaged samples while high in protein content would on analysis show a large percentage of light-colored or starchy kernels.

A study of frequency diagrams indicates that wheat having a high percentage of dark kernels will show considerable variation in protein content. The frequency diagram for the 1925 crop shows that wheat containing 95 to 100 per cent of dark kernels varied from 10 to 19 per cent in protein content. The coefficient of correlation of the 1922 crop is high because of the fact that samples from this crop containing a high percentage of dark kernels show relatively less spread in protein content than other crops.

[4] MANGELS, C. E., and SANDERSON, T. THE CORRELATION OF THE PROTEIN CONTENT OF HARD RED SPRING WHEAT WITH PHYSICAL CHARACTERISTICS AND BAKING QUALITY. Cereal Chem. 2: 107–112. 1925.

FREQUENCY DISTRIBUTIONS OF SAMPLES ON THE BASIS OF DARK-KERNEL CONTENT

A study of frequency distribution of samples on the basis of dark-kernel content has brought out some interesting facts.

TABLE 2.—*Frequency distribution of samples of hard red spring wheat on the basis of dark-kernel content*

Class[a]	1922 crop		1923 crop		1924 crop		1925 crop	
	Frequency	Percentage of total samples	Frequency	Percentage of total samples	Frequency	Percentage of total samples	Frequency	Percentage of total samples
10	0		2	1.00	12	3.79	0	
20	0		5	2.51	8	2.53	0	
30	0		7	3.51	6	1.89	2	0.45
40	2	2.22	13	6.53	6	1.89	5	1.14
50	3	3.33	14	7.03	12	3.79	12	2.75
60	8	8.88	20	10.05	13	4.11	21	4.81
70	10	11.11	25	12.56	31	9.81	21	4.81
80	16	17.77	38	19.09	53	16.77	47	10.77
90	29	32.22	50	25.12	109	34.49	77	17.66
100	22	24.44	25	12.56	66	20.88	251	57.56
Total	90		199		316		436	

[a] The class mark denotes the mid-point of the group. For example, the 80 class includes all samples containing from 75 to 85 per cent kernels, the last class (100) includes samples containing from 95 to 100 per cent of dark kernels.

Table 2 gives frequency distribution on the basis of dark-kernel content for samples from the four crops studies. Figures 1 and 2 show distribution for the crops of 1924 and 1925. It will be noted from Table 2 that in all the crop years recorded more than half the samples were found in the three highest classes; which means that when graded more than half of the total samples would fall into the dark northern spring subclass. The data in Table 2 were obtained through crop surveys and, in the writer's opinion, represent a fairly accurate cross section of the North Dakota crop for the years given. Table 2 indicates that in 1925 over 85 per cent of the North Dakota crop would fall in the dark northern spring subclass, that is, it contained 75 per cent or more of dark kernels.

The frequency distributions of samples on the basis of dark-kernel content when plotted give, with one exception, the same type of curve.[5] The frequency distribution curves from the crops of 1922, 1923, and 1924 can be shown by calculation to be Pearson's normal type I curve, and in all cases are skewed to the right. The data for 1925 give a Pearson's J-shaped type I curve. All the distribution curves show similarity in that they are skewed to the right.

FREQUENCY DISTRIBUTIONS OF SAMPLES ON THE BASIS OF PROTEIN CONTENT

The frequency distributions of samples on the basis of protein content are shown in Table 3 and in Figure 3. For three of the four years (1922, 1924, and 1925) the greatest frequency is found at 11 per cent. The frequency distribution curves for these data (fig. 3) can be shown by calculation to be Pearson's type I curve, that is,

[5] PEARSON, K. TABLES FOR STATISTICIANS AND BIOMETRICIANS. PART I. Ed. 2, 143 p., illus. [Cambridge, Eng. 1924.]

with the exception of the 1924 crop, in which the distribution apparently follows Pearson's type VI curve. The curves for these distributions show similarity in that they are in all cases skewed to the

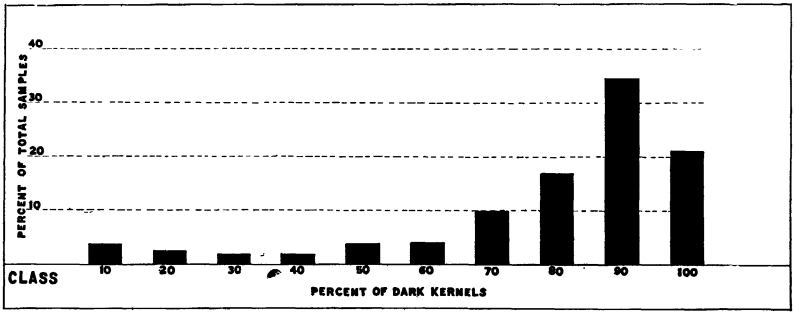

FIG. 1.—Distribution on the basis of dark-kernel content of samples from North Dakota spring-wheat crop for 1924

left. The 1923 data show the least and the 1925 the greatest skewness. The frequency distributions for protein content show appreciable skewing to the left, but as has been previously pointed out, the frequency distributions on the basis of dark-kernel content

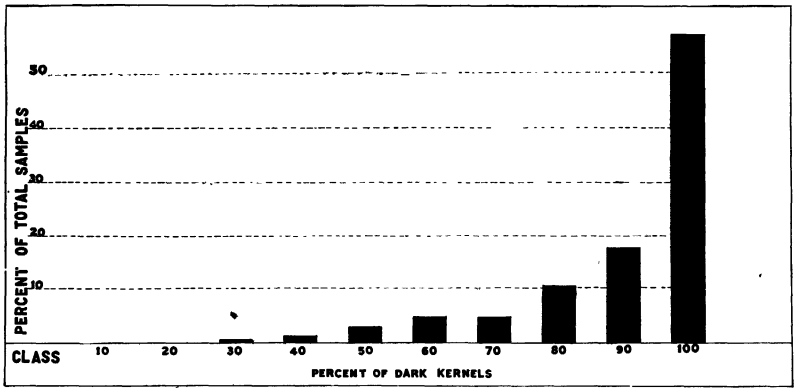

FIG. 2.—Distribution on the basis of dark-kernel content of samples from North Dakota spring-wheat crops, 1925

in all cases were skewed to the right. If a high degree of correlation existed between protein content and dark-kernel content, one would expect to find the distributions skewed in the same direction.

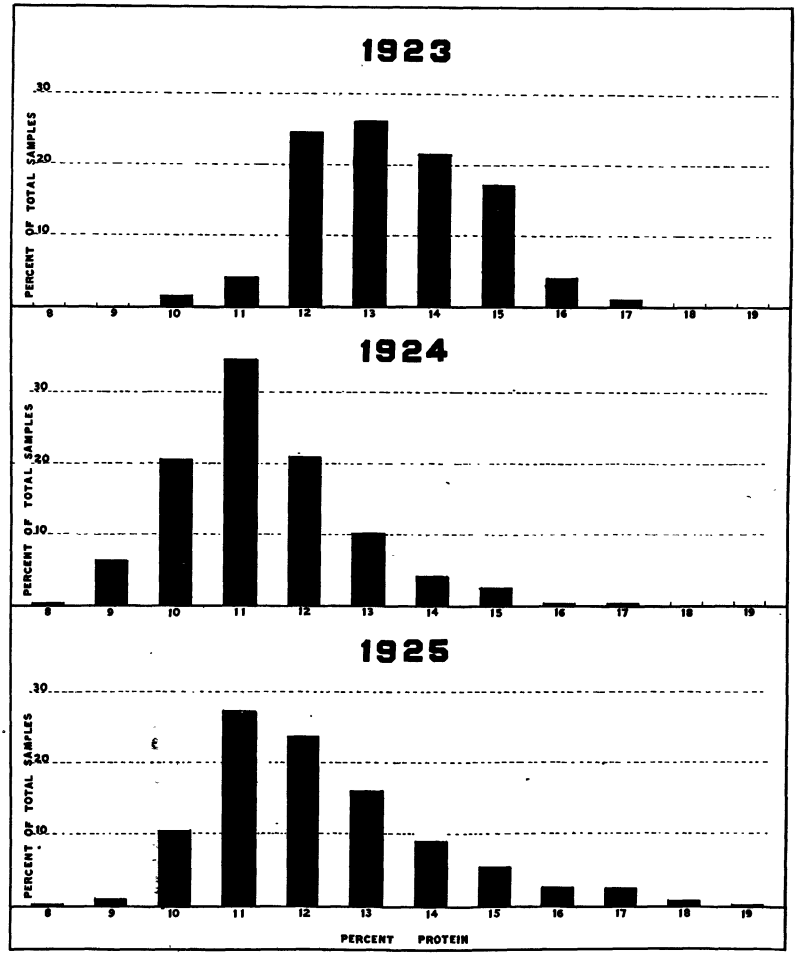

FIG. 3.—Distribution on the basis of protein content of samples from North Dakota spring-wheat crops, 1923–1925

TABLE 3.—*Frequency distribution of samples of hard red spring wheat on the basis of protein content*

Class [a]	1922 crop		1923 crop		1924 crop		1925 crop	
	Frequency	Percentage of total samples	Frequency	Percentage of total samples	Frequency	Percentage of total samples	Frequency	Percentage of total samples
8	0		0		1	0.32	1	0.23
9	3	3.33	0		20	6.33	4	.92
10	11	12.22	3	1.51	65	20.57	45	10.32
11	24	26.67	8	4.02	109	34.49	119	27.41
12	16	17.78	49	24.62	66	20.89	104	23.74
13	17	18.87	52	26.13	32	10.12	70	16.06
14	14	15.56	43	21.61	13	4.11	40	9.17
15	2	2.22	34	17.09	8	2.53	24	5.50
16	2	2.22	8	4.02	1	.32	12	2.75
17	1	1.11	2	1.01	1	.32	12	2.75
18	0		0		0		4	.92
19	0		0		0		1	.23
Totals	90		199		316		436	

[a] The class mark denotes the mid-point of the class. For example, the 12 per cent class includes all samples which fall within the range of 11.5 to 12.5 perent protein.

PROTEIN VARIATION AND DARK-KERNEL CONTENT

The wide variation in protein content of samples showing a high percentage of dark kernels was discussed briefly under correlation studies. Figures 4, 5, and 6 show the spread in protein content for (1) all samples, (2) samples containing more than 75 per cent of dark kernels, and (3) samples containing more than 85 per cent of dark kernels.

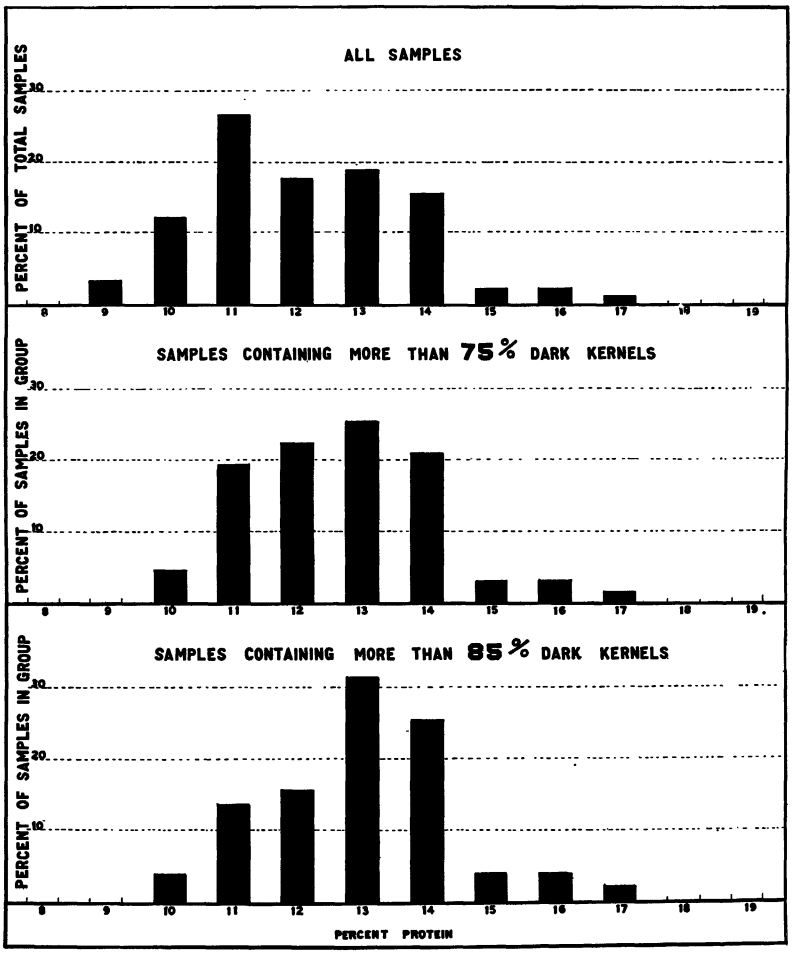

FIG. 4.—Distribution on the basis of protein content of samples from North Dakota spring-wheat crops for 1922

Figures 4, 5, and 6 show that the spread in protein content in groups containing more than 75 per cent or more than 85 per cent of dark kernels is almost as large as the protein spread for all samples. In 1925 the protein content for all samples varied from 8 to 19 per cent, as shown by Figure 3, but the spread for the 75 and 85 per cent dark-kernel groups was almost as great—9 to 19 per cent. In 1924 the protein varied in all samples from 8 to 17 per cent, and the variation

for the 75 and 85 per cent dark-kernel groups was from 9 to 17 per cent. The 1923 crop averaged higher in protein than the 1924 and 1925 crops, but the spread in protein content for all samples was from 10 to 17 per cent, and the variation in the 75 and 85 per cent dark-kernel groups was from 11 to 17 per cent. The 1922 crop shows a greater degree of correlation between dark kernels and protein content

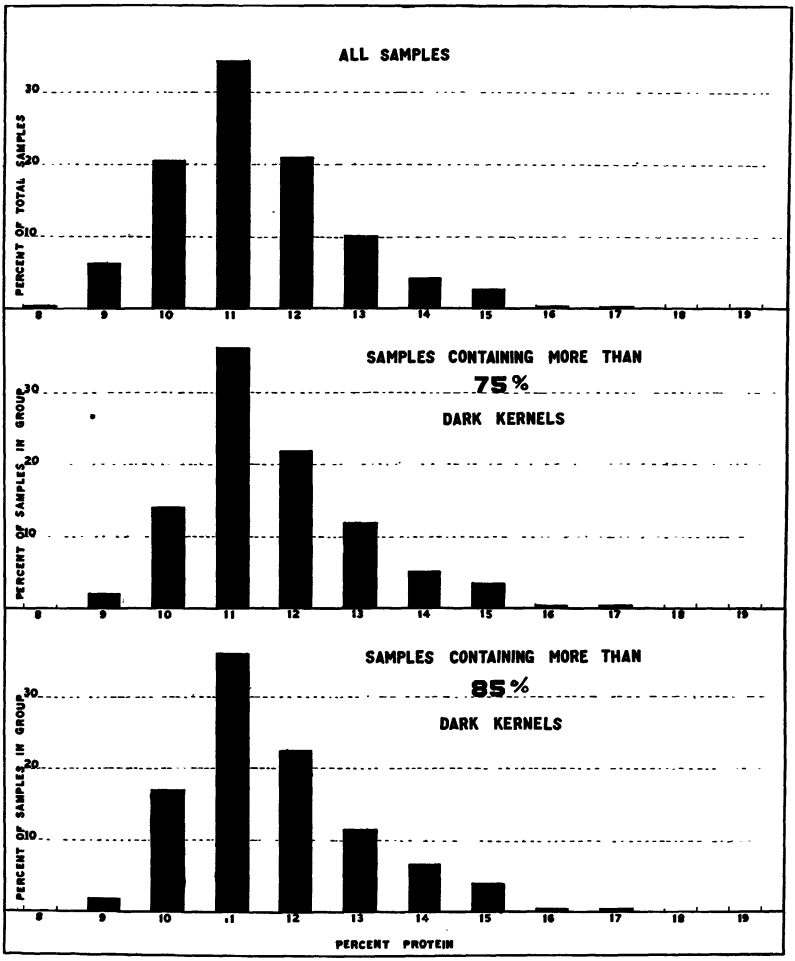

FIG. 5.—Distribution on the basis of protein content of samples from North Dakota spring-wheat crop for 1924

than other crops studied, but the spread in protein content for all samples of the 1922 crop was from 9 to 17 per cent, and the variation in the 75 and 85 per cent dark-kernel groups was from 10 to 17 per cent.

For the 1924 and 1925 crops the greatest frequency (figs. 5 and 6) for all samples is found in the 11 per cent class, but the greatest frequency for the 75 and 85 per cent groups is also found in the 11 per cent class.

For the 1923 crop the greatest frequency is found in the 13 per cent class for all samples, but the greatest frequency for the 75 per cent dark-kernel group again occurs in the same class (13 per cent).

The 1922 crop (fig. 4), as would be expected from the correlation coefficient, differs quite distinctly from the other crops. The greatest frequency for all samples of the 1922 crop occurs in the 11 per cent

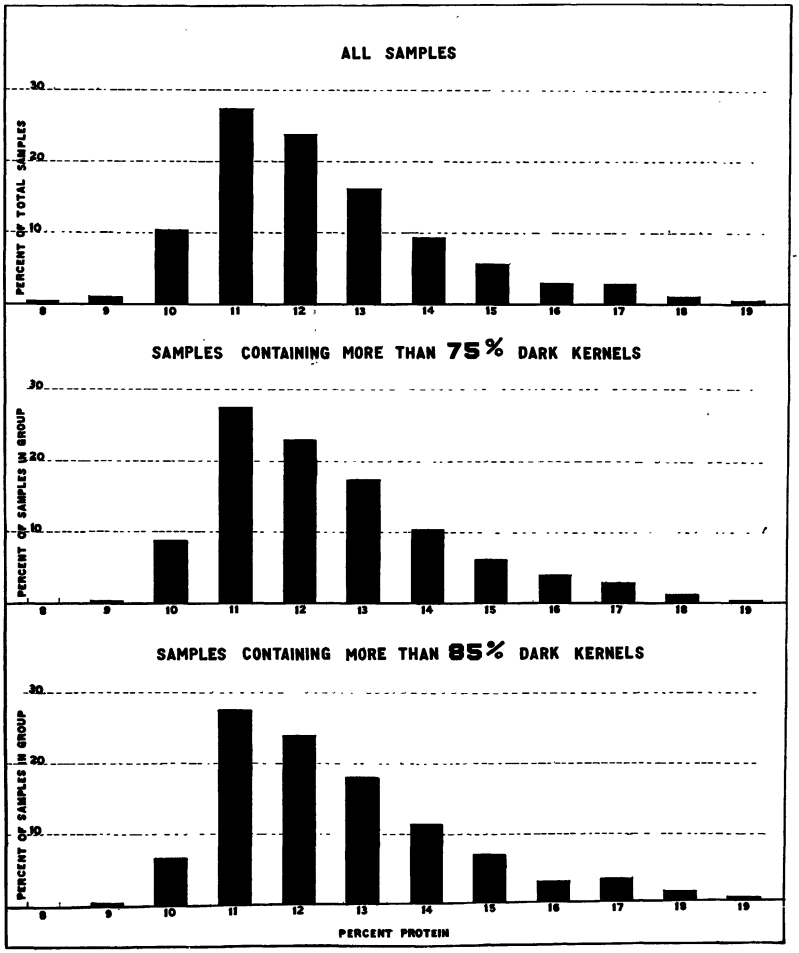

FIG. 6.—Distribution on the basis of protein content of samples from North Dakota spring-wheat crop for 1925

class, and in this respect the crop is similar to the 1924 and 1925 crops, but the greatest frequency for the 75 per cent and 85 per cent dark-kernel groups is found in the 13 per cent class.

In Table 4 the samples are grouped in such a way as to bring out the relation of dark-kernel protein content to protein content of all samples. As will be noted, the 1922 crop shows a larger increase in protein for the 75 and 85 per cent dark-kernel groups than any crop of the other three years.

TABLE 4.—*Comparison of mean protein content of dark kernels and of kernels of all samples in hard red spring wheat, 1922–1925*

Year	Mean protein content of—		
	All samples	Samples containing more than 75 per cent of dark kernels	Samples containing more than 85 per cent of dark kernels
	Per cent	*Per cent*	*Per cent*
1922	12.12	12.67	12.98
1923	13.35	13.48	13.45
1924	11.35	11.56	11.66
1925	12.31	12.43	12.53

In the 1922 crop there is apparent a significant degree of correlation between dark kernels and protein content, but it was in 1922 that the protein test was first used extensively on the Minneapolis market. The 1922 crop shows a higher degree of correlation than the crops which followed, but even with this crop, the dark-kernel content was not considered sufficiently accurate as an index of protein content, and the grain trade began to use the protein test. The dark-kernel content is apparently of very questionable value in estimating the potential baking value of a lot of wheat. A high percentage of dark kernels does not assure the wheat buyer that he is getting a wheat that is high in protein, and for this reason the protein test is now considered by many buyers of equal importance with the grade certificate.

SUMMARY

Correlation between dark kernels and protein content shows considerable seasonal variation, and the degree of correlation may be quite low.

Frequency distributions of representative samples from North Dakota spring-wheat crops indicate that in every year of the four recorded a large proportion of the crop contained a high percentage of dark kernels and would fall in the highest subclasses when graded.

Frequency distributions of samples on the basis of dark-kernel content are skewed to the right, while distributions on the basis of protein content are skewed to the left, a fact which indicates a lack of close relationship between dark kernels and protein content.

Frequency distributions of samples containing more than 75 per cent or more than 85 per cent of dark kernels, respectively, when compared to distributions for all samples show (1) that total spread or variation in protein content is almost as great in 75 per cent or 85 per cent dark-kernel groups as in the total samples; (2) when distributions of all samples are compared with distributions of samples containing more than 75 per cent or more than 85 per cent of dark kernels, the greatest frequency falls in the same class in all groups, except in the case of the 1922 crop, where the greatest frequency moves up two classes—that is, into the 75 and 85 per cent

dark-kernel groups; (3) the mean of samples containing 85 per cent and 75 per cent, respectively, of dark kernels is very little larger than the mean of all samples except in 1922, when a significant increase is noted.

The color of the kernel is not a sufficiently accurate index of protein content to be used by the wheat buyer, and for this reason is being superseded by actual protein test. As an index of wheat quality, dark-kernel content is of questionable value.